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Lecture 11

Networking

Game Networking Issues

Consistency

- Do our games agree?
  - Where do I see objects?
  - Where do you see them?
  - Who is **authoritative**?
- How to force agreement?
  - Do I wait for everyone?
  - Do I guess and fix errors?

Security

- What cheats are possible?
  - View hidden data
  - Enter invalid states
  - Improve player skill
- How do we cheat proof?
  - Technical solutions?
  - Community policing?

Game Networking Issues

Consistency

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Today's Lecture

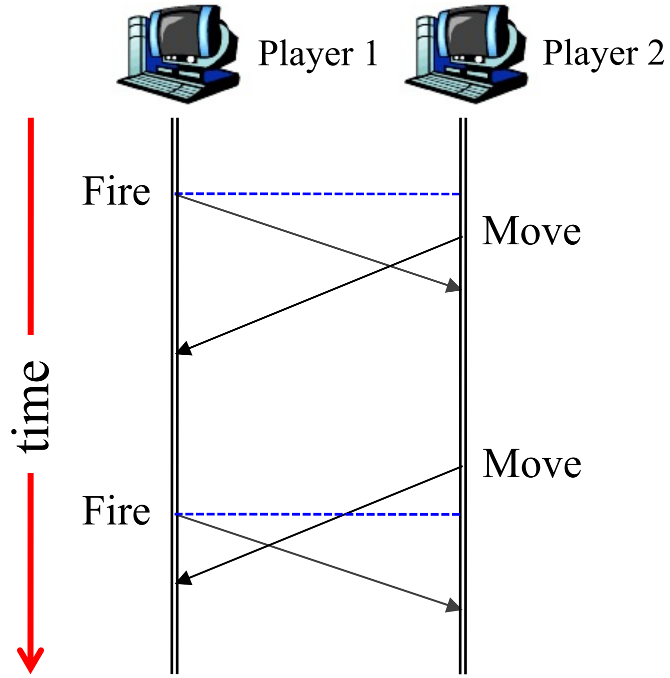
Security

- What cheats are possible?
  - View hidden data
  - Enter inval
- How do we cheat proof?
  - Technical solutions?
  - Community policing?

Not going to cover

The Issue of Consistency

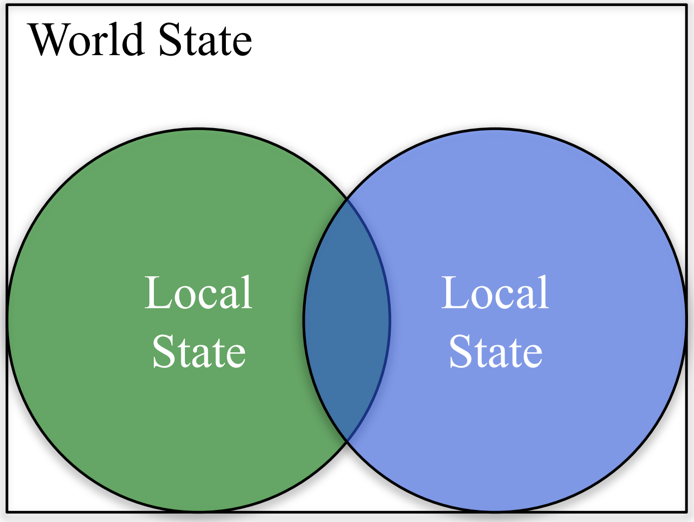
- *Latency* is root of all evil
  - **Local** actions are instant
  - **Network** actions are slow
- **Example**: targeting
  - Want "geometric fidelity"
  - Fire a weapon along ray
  - Hits first object on ray
  - But movement is fast!



How to tell these cases apart?

World State vs. Local State

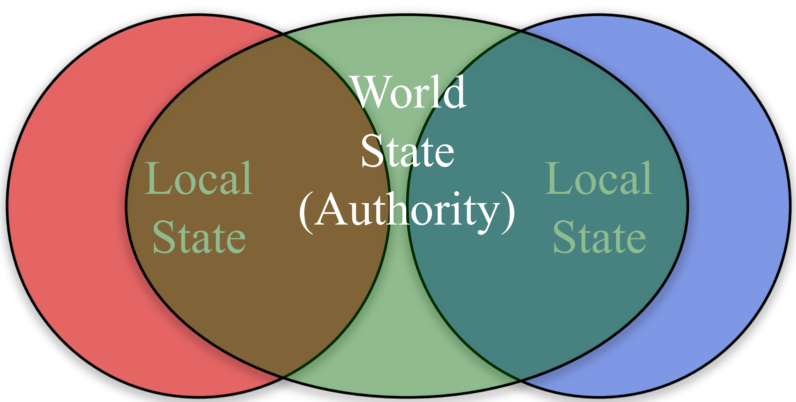
- **State**: all objects in game
  - **Local State**: on a machine
  - **World State**: “true” state
- *Where* is the world state?
  - On a single machine?
  - Union of local states?
- States may be *inconsistent*
  - Local disagrees with world
  - Is this really a problem?
  - What can we do about it?



The Question of Authority

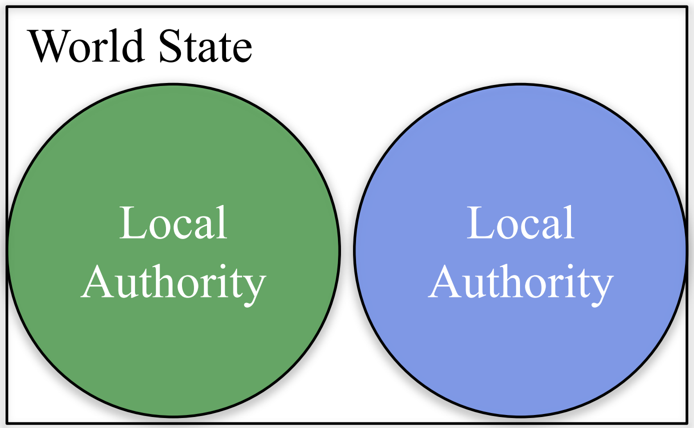
Centralized Authority

- One computer is authority
  - Stores the full world state
  - Local states must match it
- Often call this the "server"

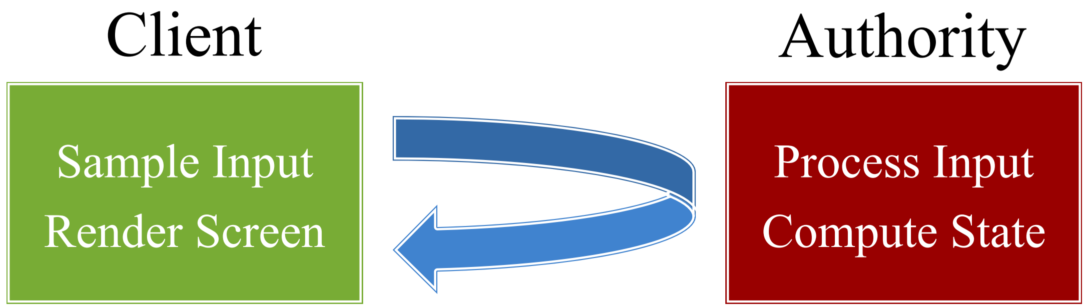


Distributed Authority

- Authority is divided up
  - Each object has an owner
  - Must match if not owner
- Classically call this "P2P"

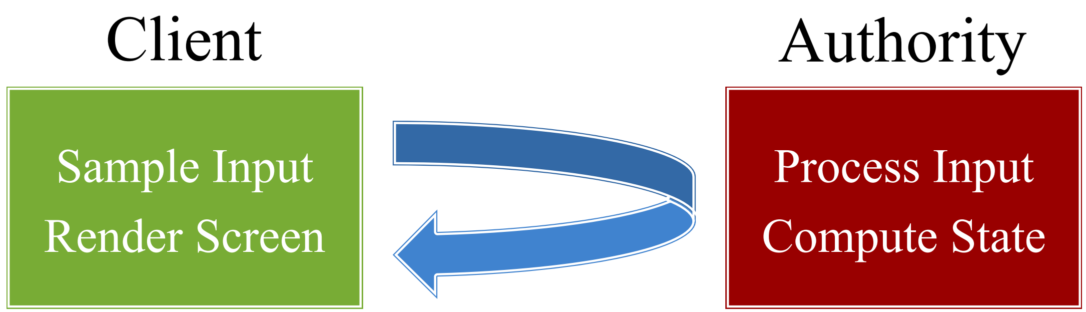


Authority and Latency



- Lack of authority enforces a delay
  - Only draw what authority tells you
  - Requires round trip from your input
  - Round-trip time (RTT) can be > 200 ms
- This makes the game less responsive
  - Need some way to compensate for this

Authority and Latency



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  -

Need to understand basics before solving this

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  - Need some way to compensate for this

Networking Breaks into Two Phases

Matchmaking

- Service to find other players
  - Groups players in a session
  - But does not run session
- Why make your own?
  - Control user accounts
  - Implement skill ladders
- 3rd party services common
  - Apple GameCenter
  - GooglePlay API
  - CUGL Docker Service

Game Session

- Service to run the core game
  - Synchronizes player state
  - Supports minor adds/drops
- Why make your own?
  - Must tailor to your game
  - You often have no choice
- Limited 3rd party services
  - Often just a networking API
  - For limited class of games
  - **Examples**: Unity, Unreal

Networking Breaks into Two Phases

Matchmaking

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  - Apple GameCenter
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Simplify if possible

Game Session

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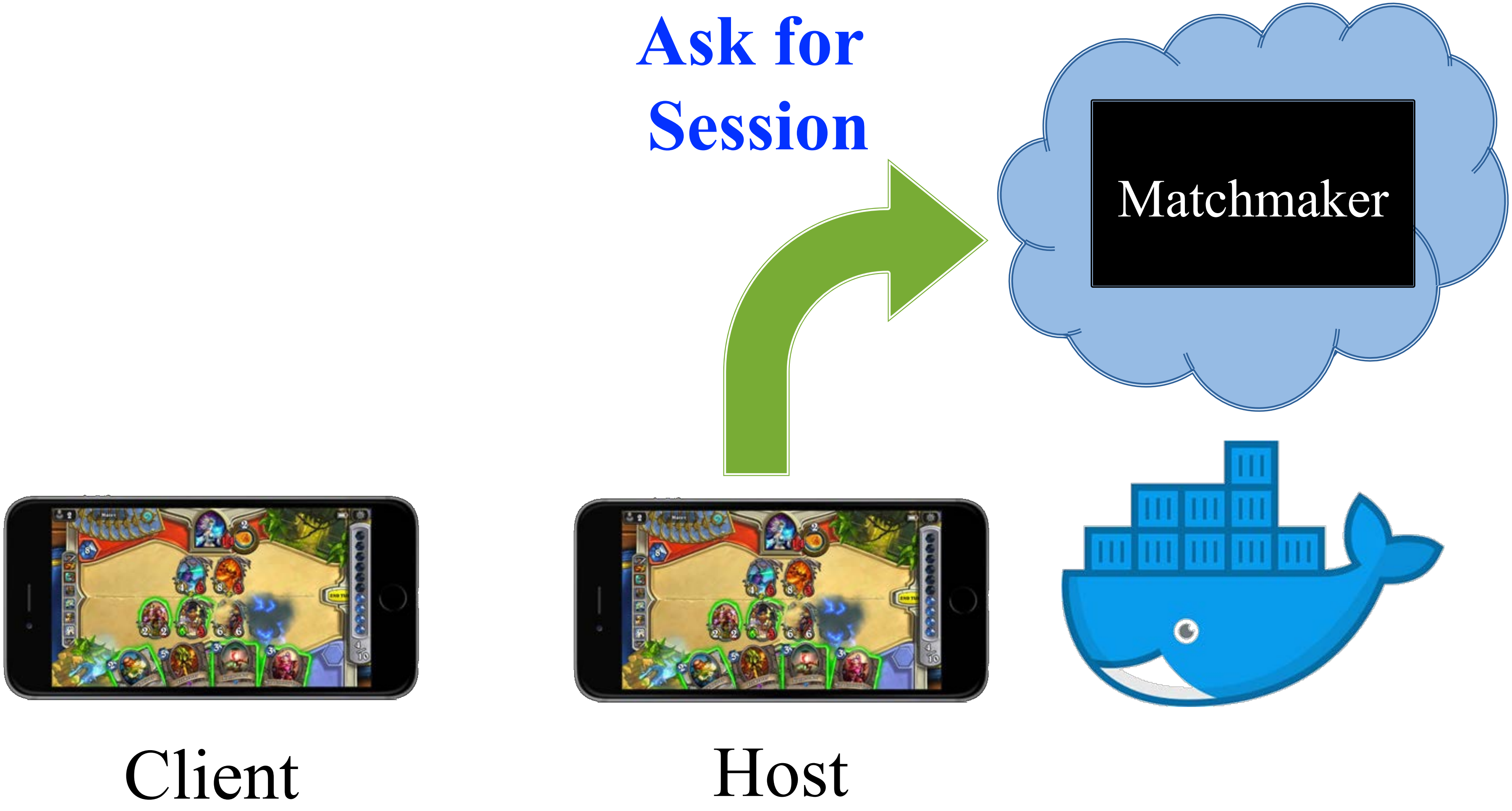
  - **Examples**: Unity, Unreal

Our main focus

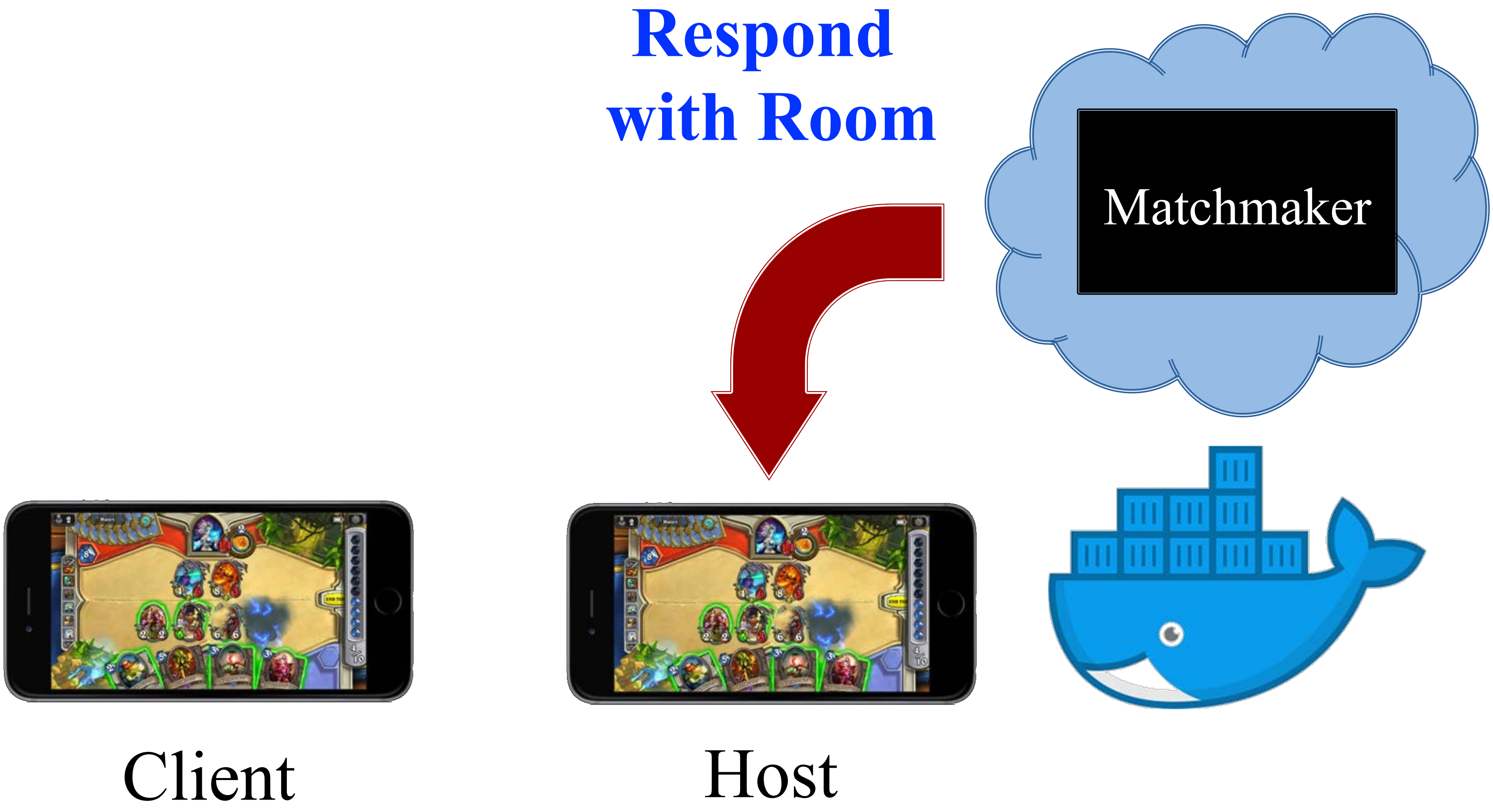
CUGL Matchmaking

- Requires a custom server
  - Needs a fixed IP address
  - IP is coded into the game
  - Or at least put in an asset
- Can leverage **cloud tech**
  - Write a Docker container
  - Deploy only as needed
- **Benefit**: cross-platform play
  - Must for iOS-Android play
  - See also Open Match

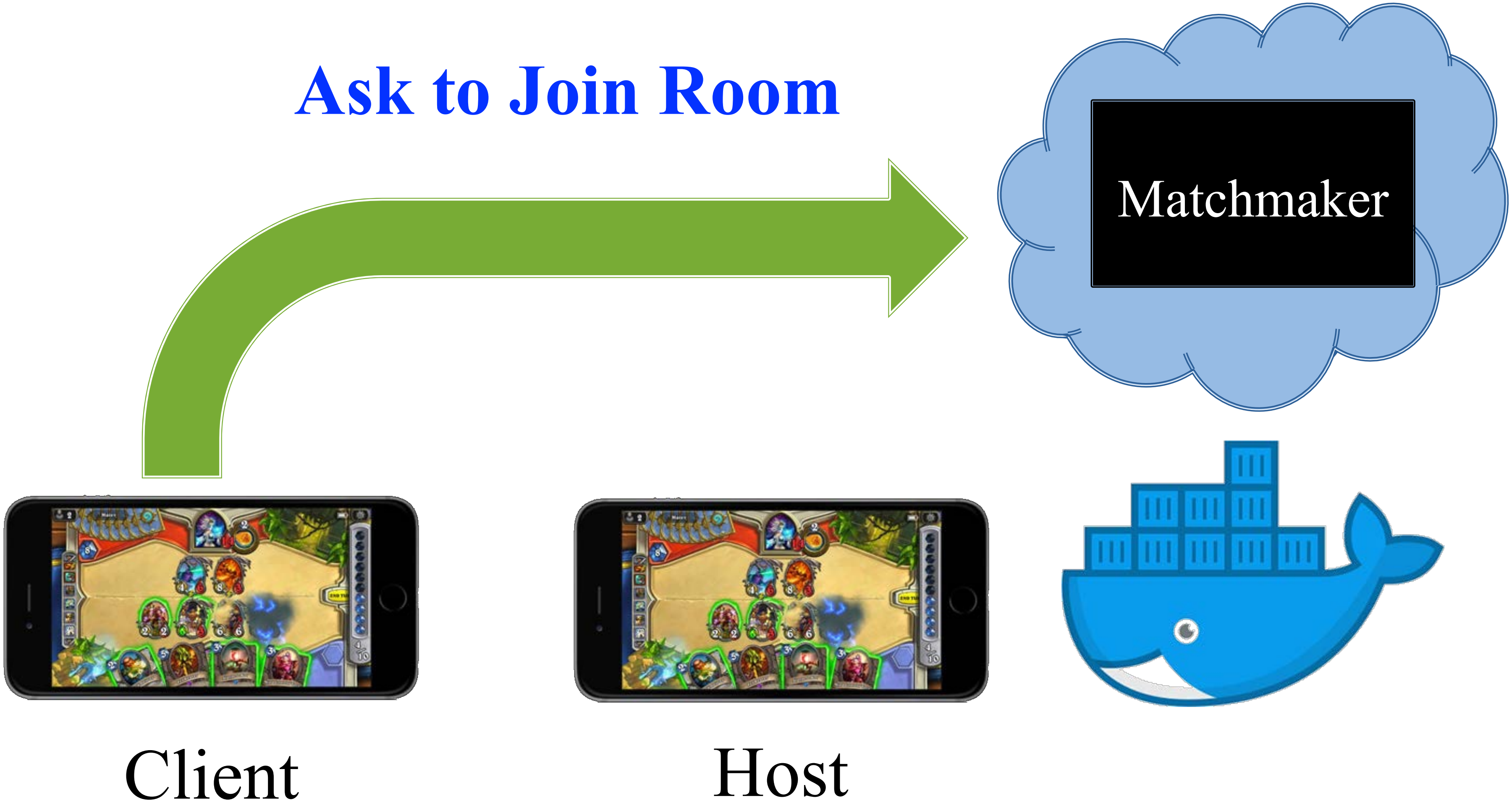
CUGL Matchmaking



CUGL Matchmaking



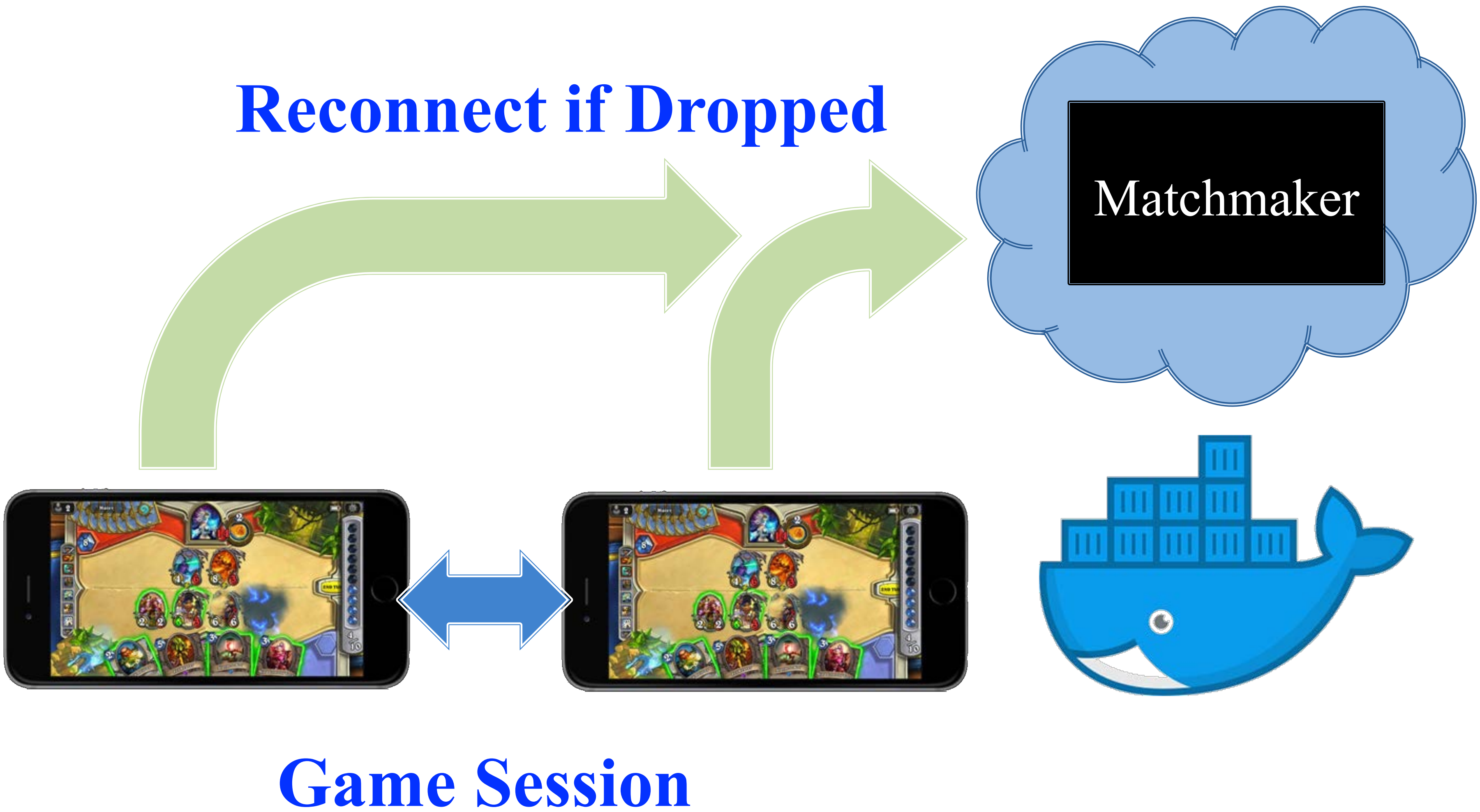
CUGL Matchmaking



CUGL Matchmaking

Game Session

CUGL Matchmaking

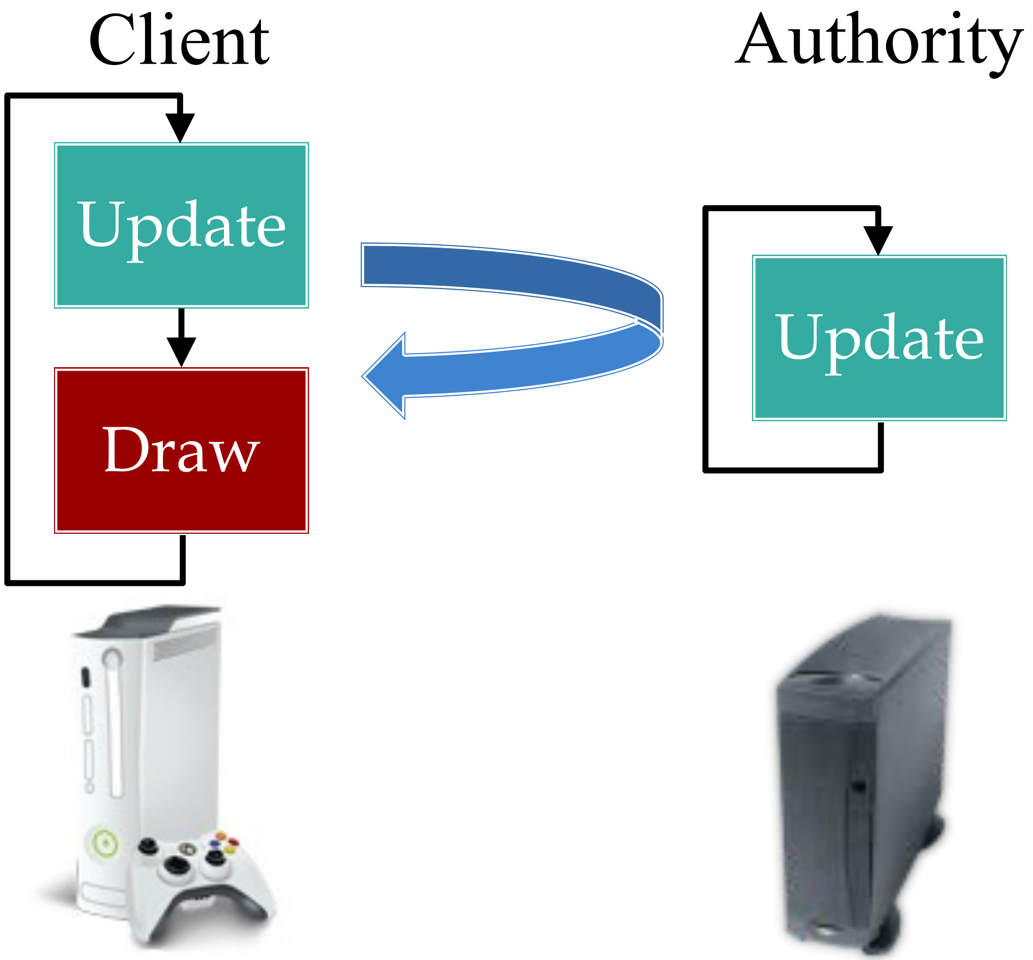


Matchmaking in *Family Style*

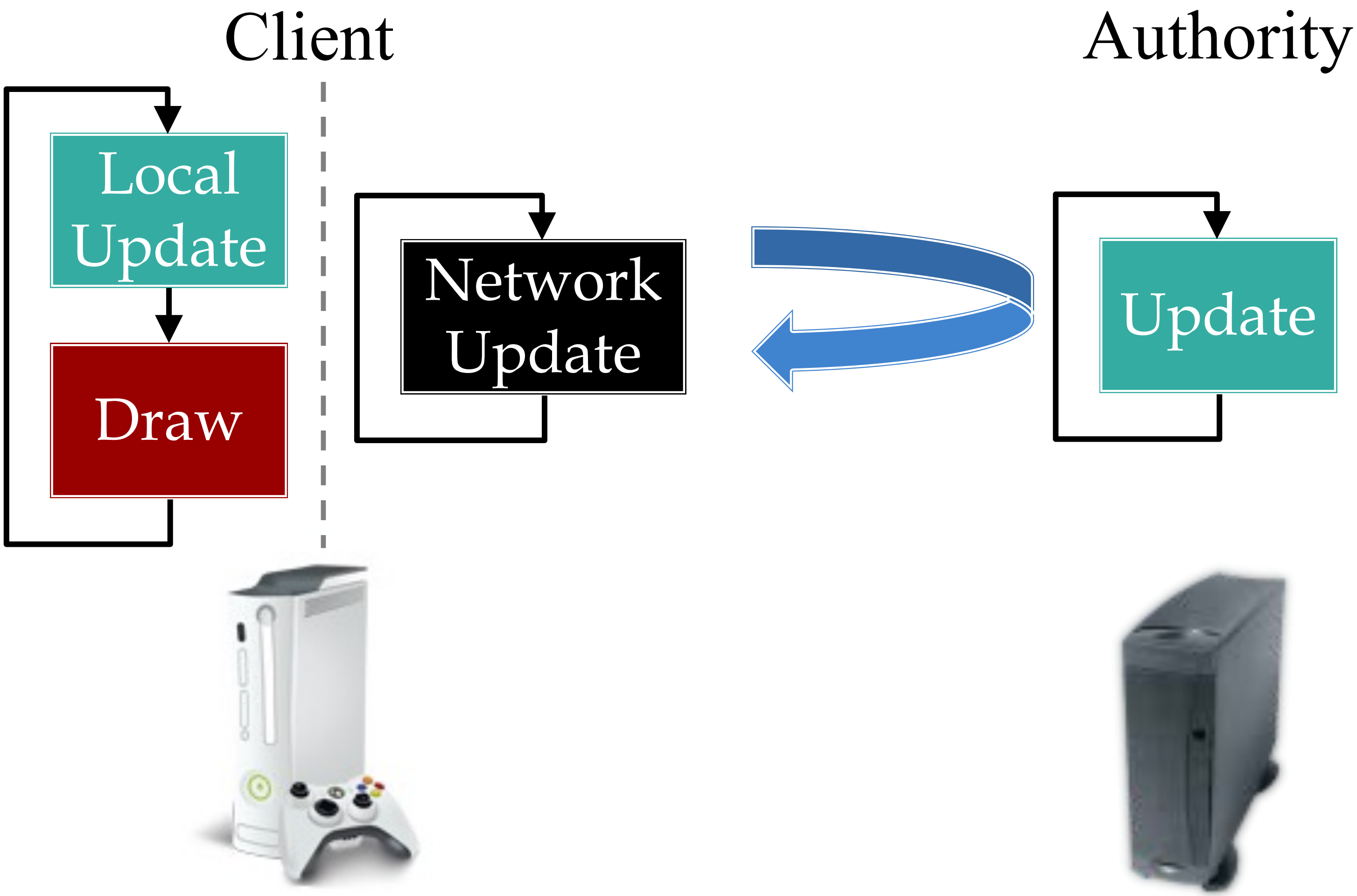
Why Not Just Direct IPs?

- **Idea:** Just let the host be "the server"
  - Player starts up server instance
  - Player writes down their IP address
  - Everyone else types in that IP address
- **Problem:** Network Address Translation
  - Most networks use NAT to attach many devices
  - This means IP addresses on NAT are not real
- Matchmaker provides **NAT punchthrough**!
  - Reason why you keep it open for reconnects

Game Session: Part of Core Loop



Decoupling the Network Loop



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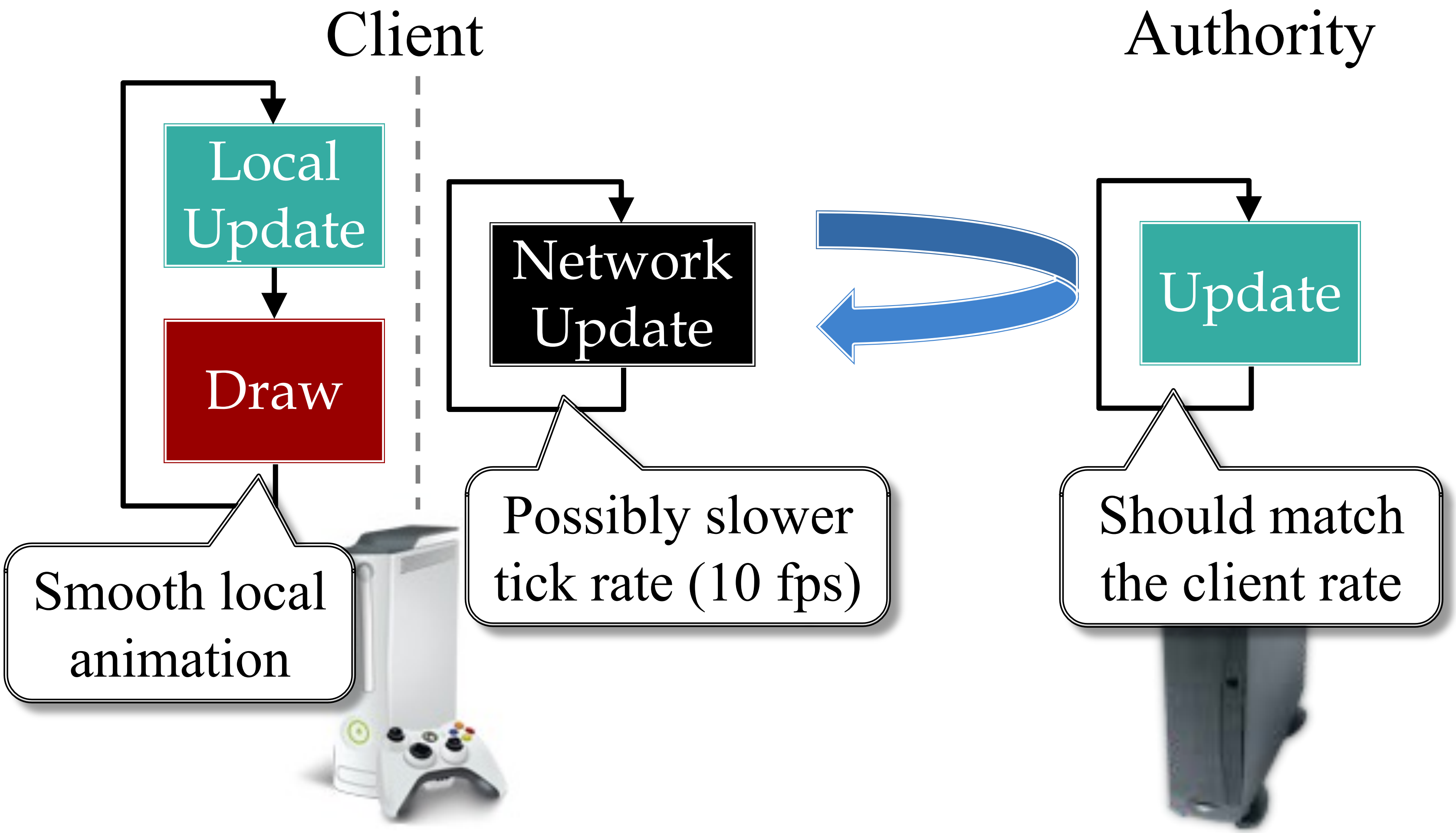
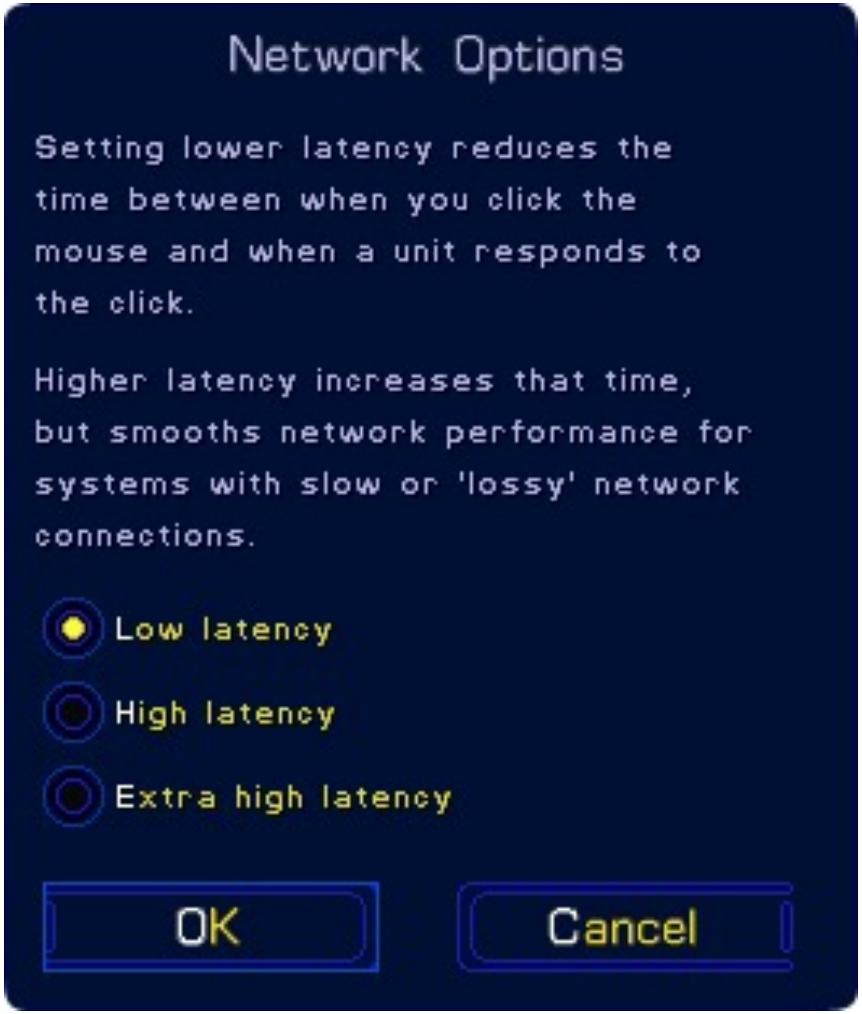
Decoupling the Network Loop



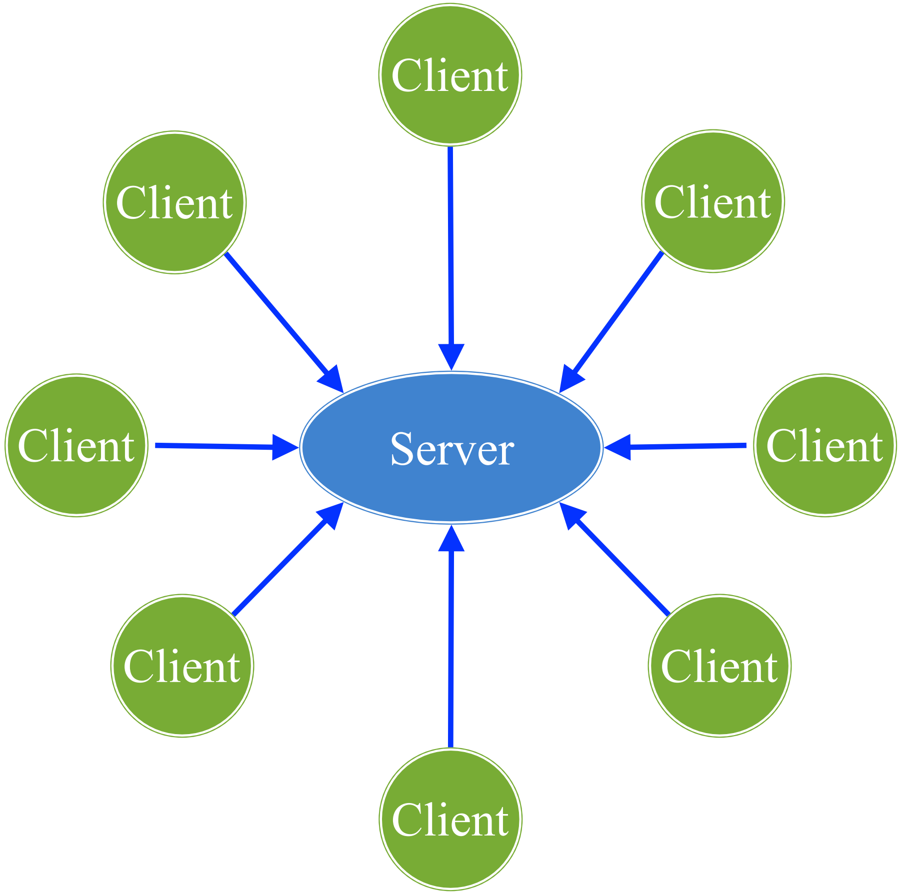
Decoupling Enables Latency Masking

- Animation is "buying time"
  - Looks fast and responsive
  - But no real change to state
  - Animation done at update
- **Examples:**
  - Players wait for elevator
  - Teleportation takes time
  - Many hits needed per kill
  - Bullets have flying time
  - Inertia limits movement



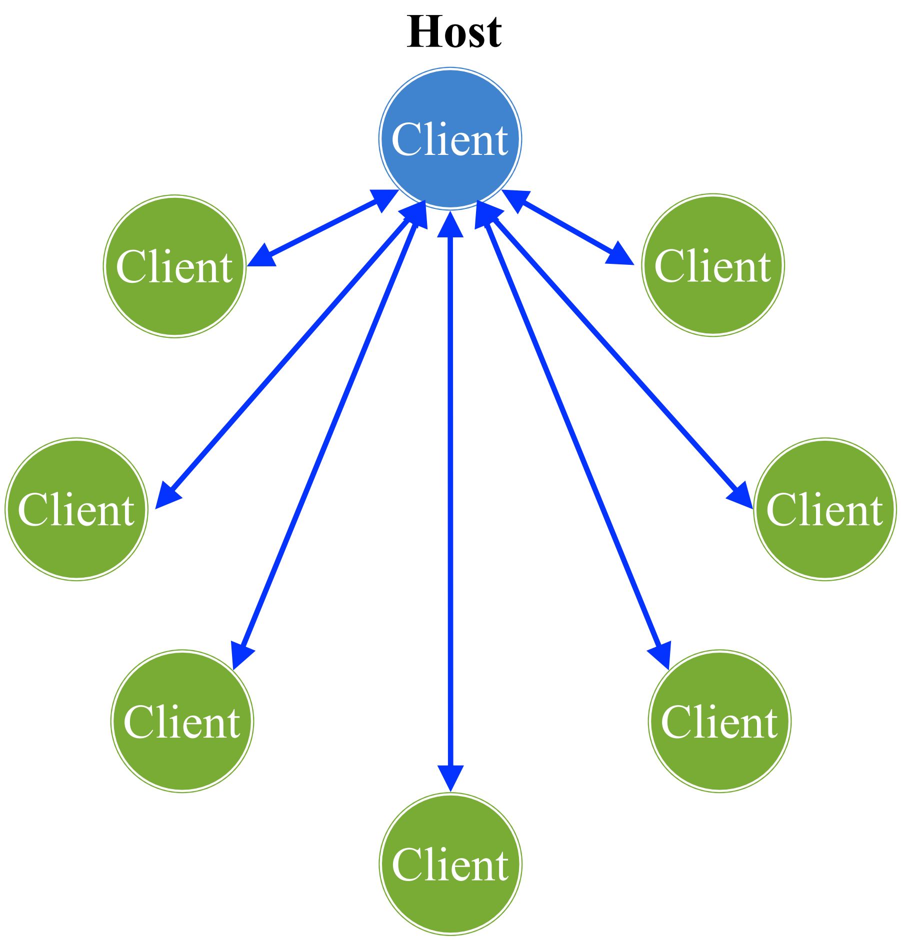
Game Session: Dedicated Server

- Server developer provides
  - Acts as central authority
  - May be several servers
  - May use cloud services
- **Pros:**
  - Could be real computer
  - More power/responsiveness
  - No player has advantage
- **Cons:**
  - Lag if players not nearby
  - Expensive to maintain



Game Session: AdHoc Server

- One client acts as host
  - Acts as central authority
  - Chosen by matchmaker
  - But may change in session
- **Pros:**
  - Cheap long-term solution
  - Can group clients spatially
- **Cons:**
  - Server is a mobile device
  - Host often has advantages
  - Must migrate if host is lost



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- **Pr**
  - n
  - lly

Predominant commercial architecture

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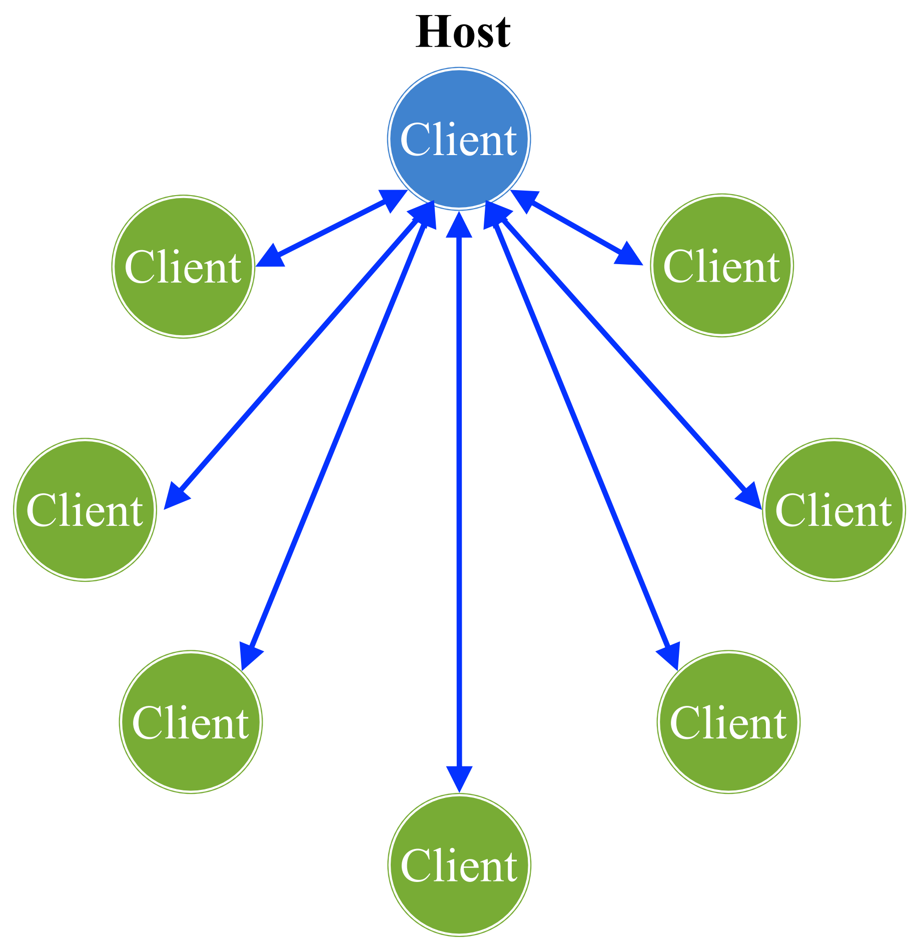

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Game Session: AdHoc Server

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Looks like the CUGL approach?

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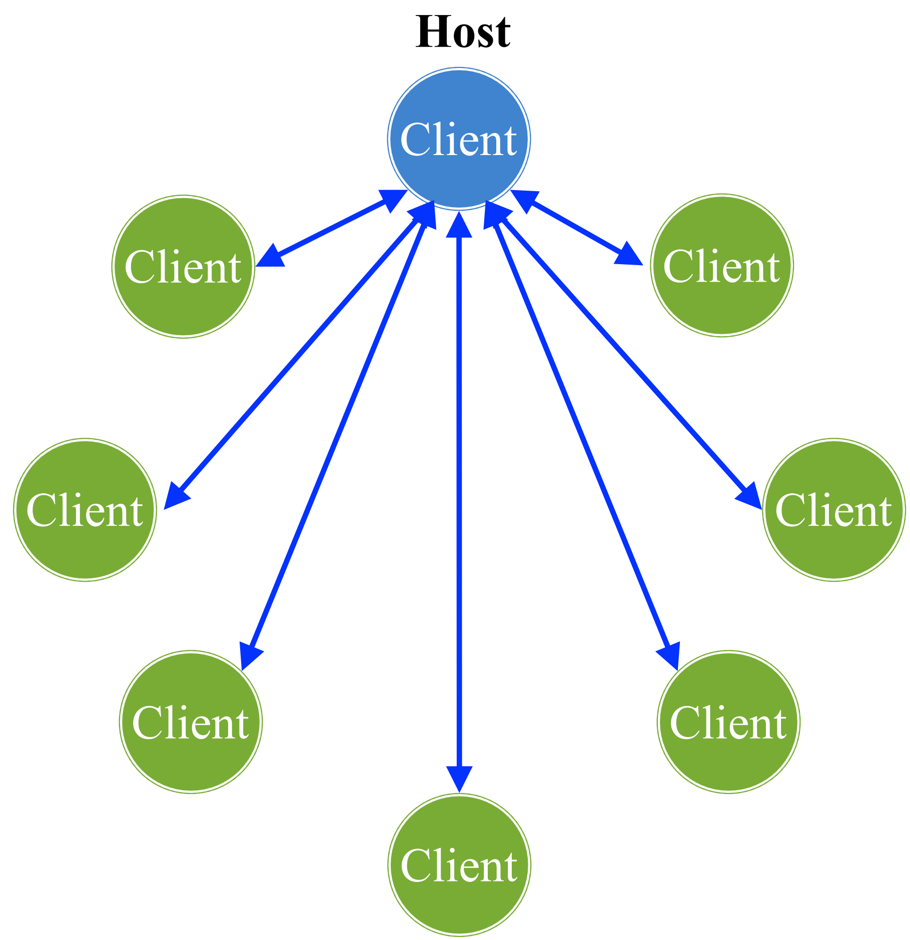
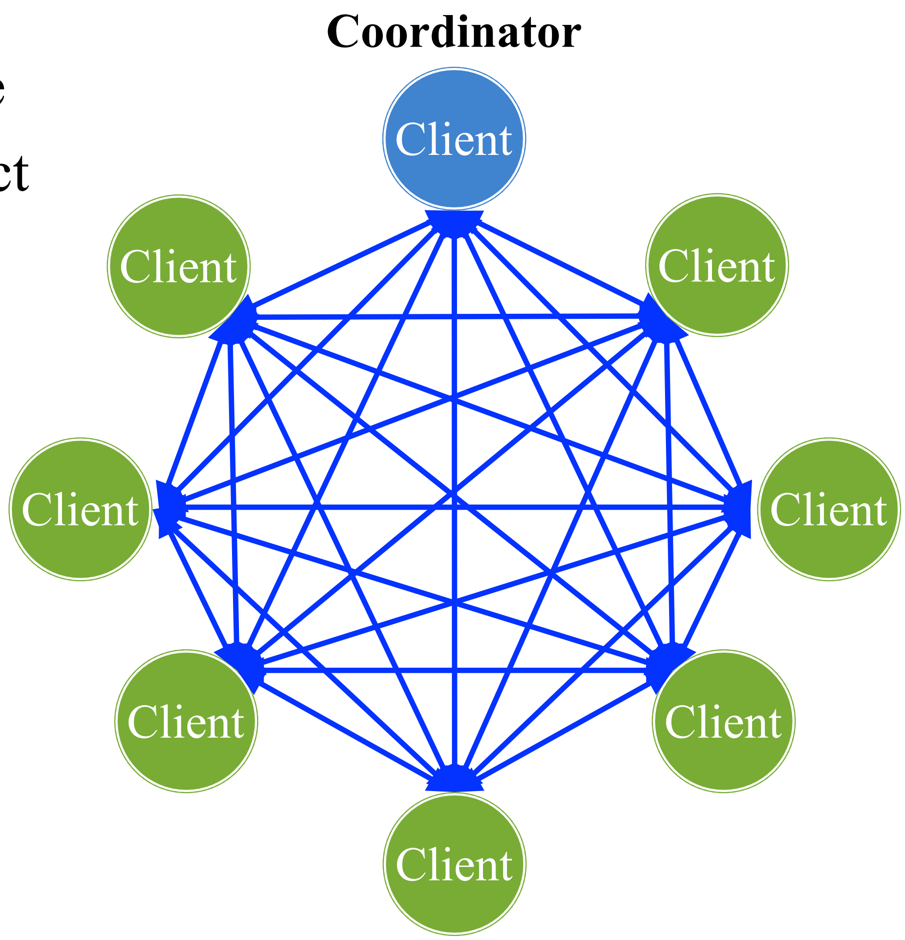


Game Session: True P2P

- Authority is distributed
  - Each client owns part of state
  - Special algorithms for conflict
  - Coordinator for adds/drops
- **Pros:**
  - No lag on owned objects
  - Lag limited to "attacks"
  - Same advantages as adhoc
- **Cons:**
  - Incredibly hard to implement
  - High networking bandwidth



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Almost no-one does this outside academia

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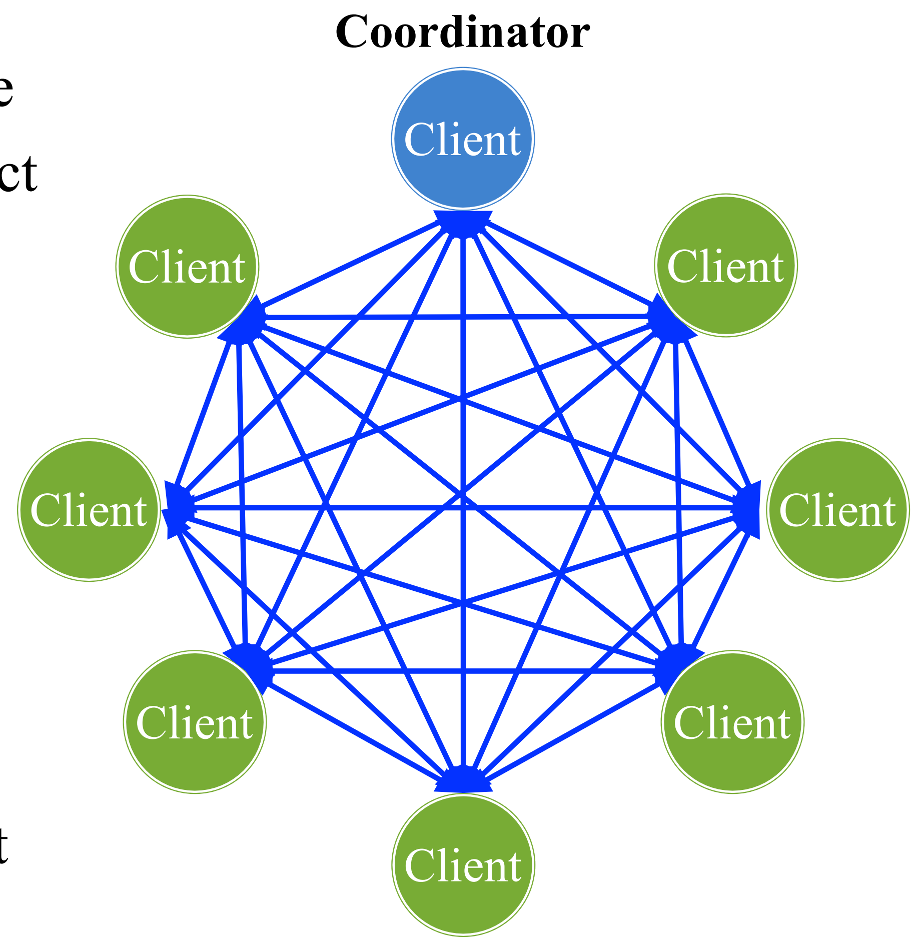


Game Session: True P2P

Game Session: True P2P

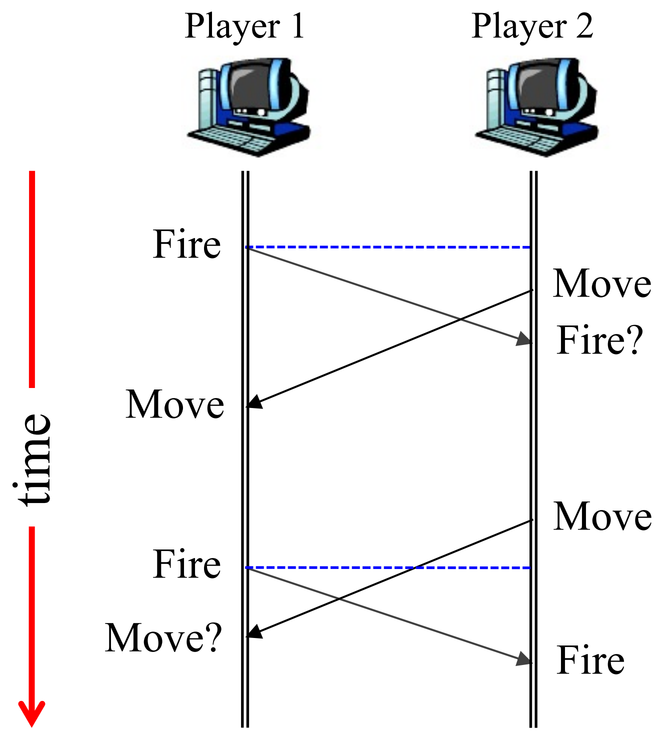
Melee is easy to latency mask!

What Do CUGL Games Use?

- There is a **designated host** in CUGL networking
  - But this used for **matchmaking**, not the session
  - No requirement that host is authoritative
- Library was actually **designed for P2P**
  - Method `send()` broadcasts to all (including host)
  - Worked because *Family Style* spaces were disjoint
- But possible to make **host authoritative**
  - Method `sendOnlyToHost()` talks only to host
  - Host **synchronizes** incoming messages
  - Broadcasts back to clients with `send()`

Synchronization Algorithms

- Clients must be **synchronized**
  - Ensure they have same state
  - … or differences do not mattter
- Synchronization != authority
  - Authority determines true state
  - Not *how* clients updated
  - Or *when* clients are updated
- Major concept in networking
  - Lots of complicated algorithms
  - Also a **patent mindfield**
  - Take distributed systems course



Synchronization Algorithms

Pessimistic

- Everyone sees same world
  - Ensure local = world state
  - Forces a drawing delay
- Best on fast networks
  - Local LAN play
  - Bluetooth proximity
- Or games with limited input
  - Real time strategy
  - Simulation games

Optimistic

- Allow some world drift
  - Best guess + roll back
  - Fix mistakes if needed
- Works on any network
  - Lag errors can be fixed
  - But fixes may be distracting
- Works great for shooters
  - Player controls only avatar
  - All else approximated

Synchronization Algorithms

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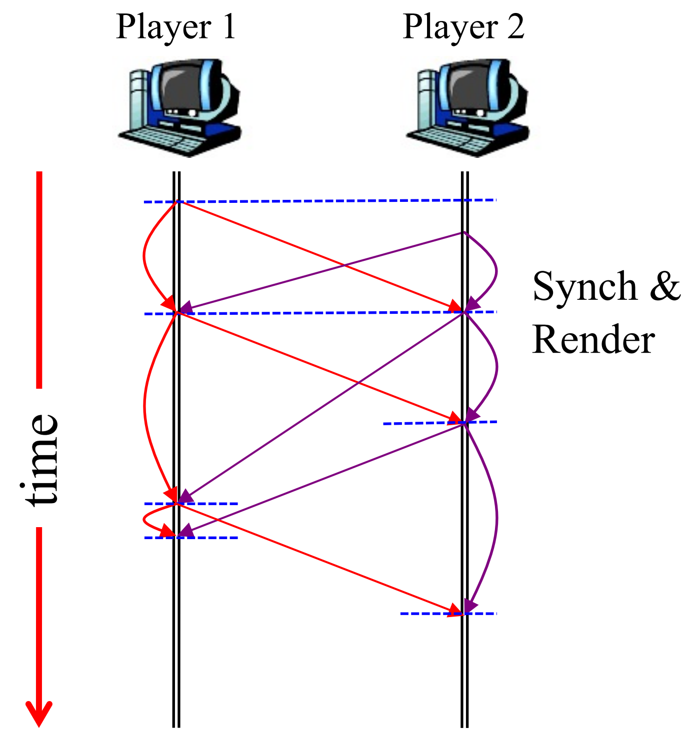
Also great for distributed authority

Pessimistic: Lock-Step Synchronization

- **Algorithm**: play by "turns"
  - Players send turn actions
  - Even if no action was taken
  - Wait for response to render
- **Problems**
  - *Long* Internet latency
  - Variable latencies (jitter)
  - Speed set by slowest player
  - What if moves are lost?
- More common in LAN days



Pessimistic: Bucket Synchronization

- **Algorithm**: turns w/ timeout
  - Often timeout after 200 ms
  - But can be adapted to RTT
  - All moves are buffered
  - Executed at end of *next* turn
- **Problems**
  - Variable latencies (> a turn)
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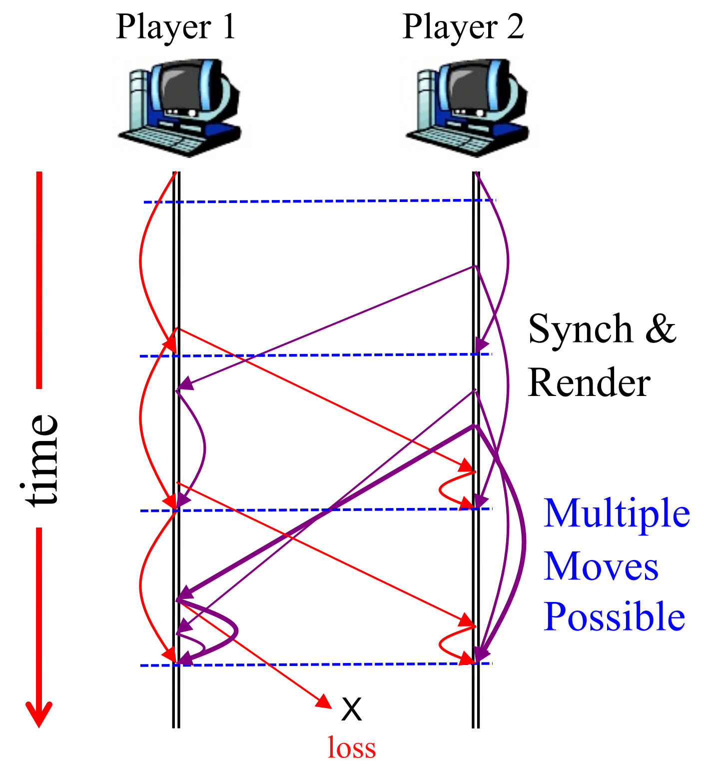
- Used in classic RTS games



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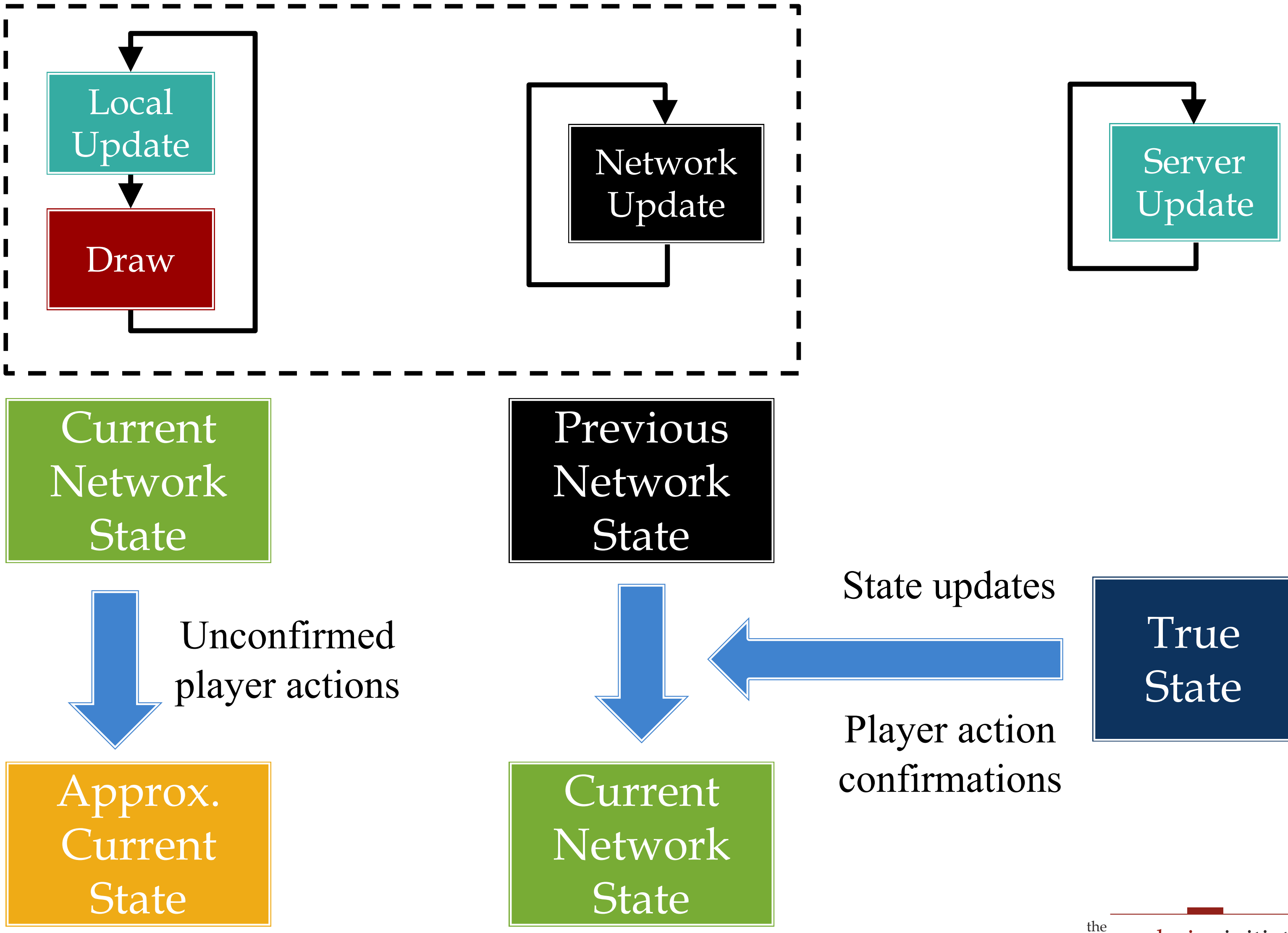
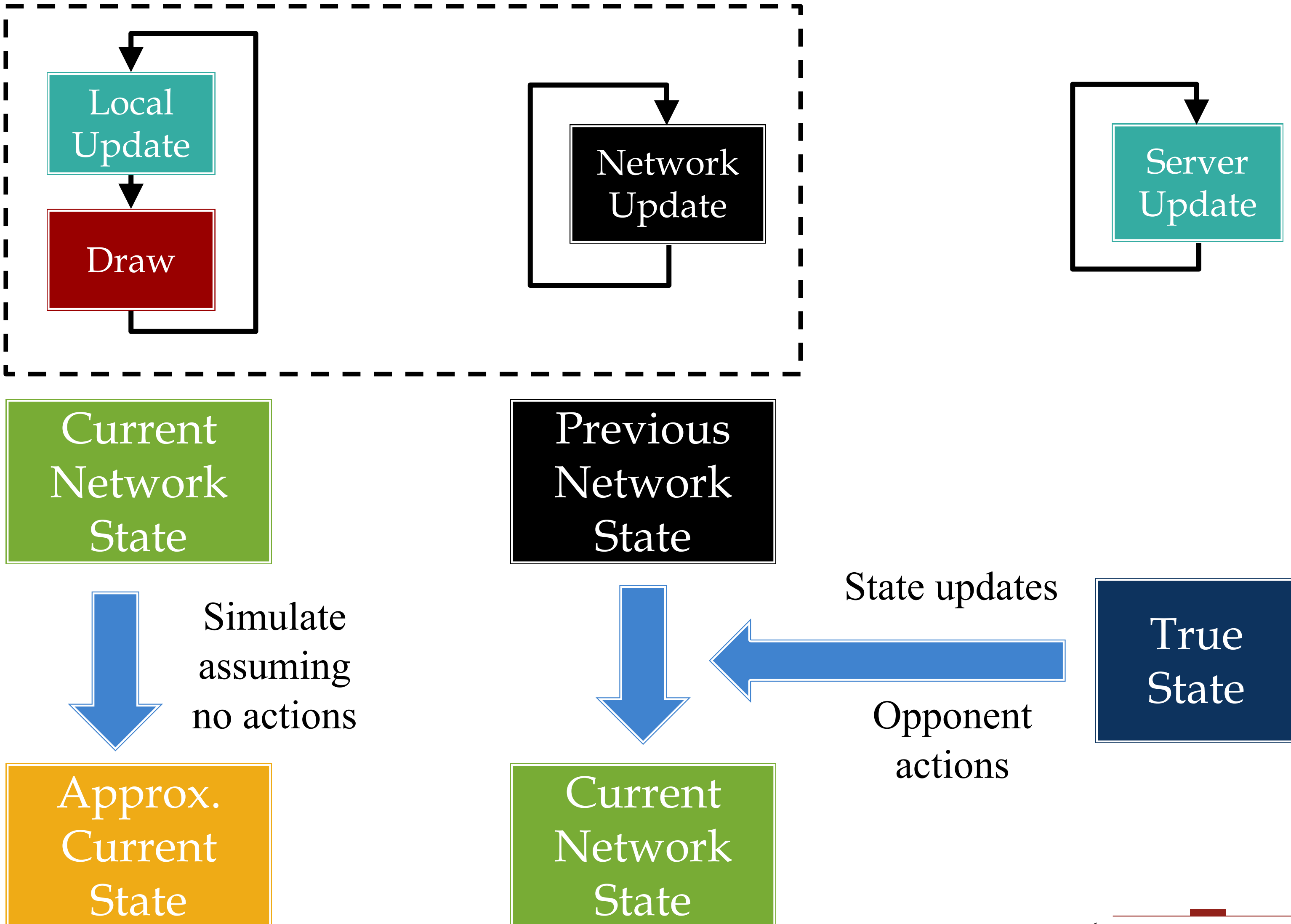
Optimistic: Personal State



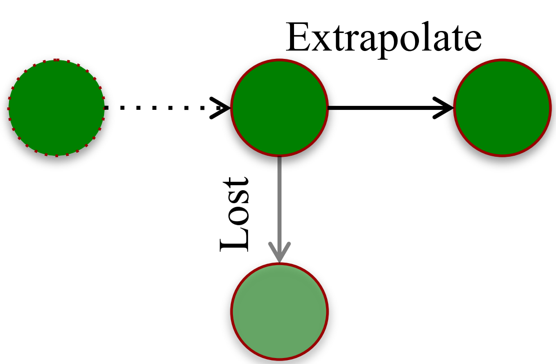
Optimistic: Opponent State



Advantages of Sending Actions

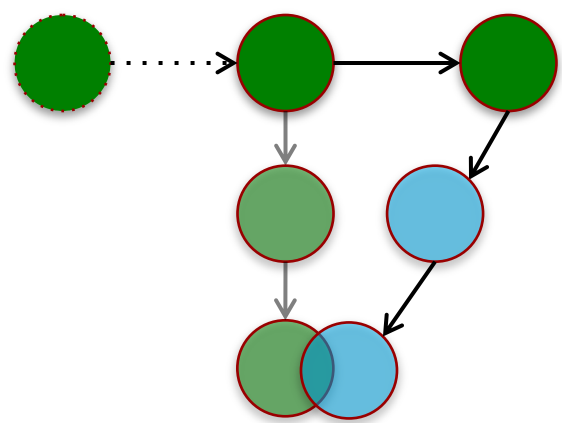
Dead Reckoning

- Assume velocity constant
  - Simulate the new position
  - Treats like physics object
- Generalize to other actions



Error Smoothing

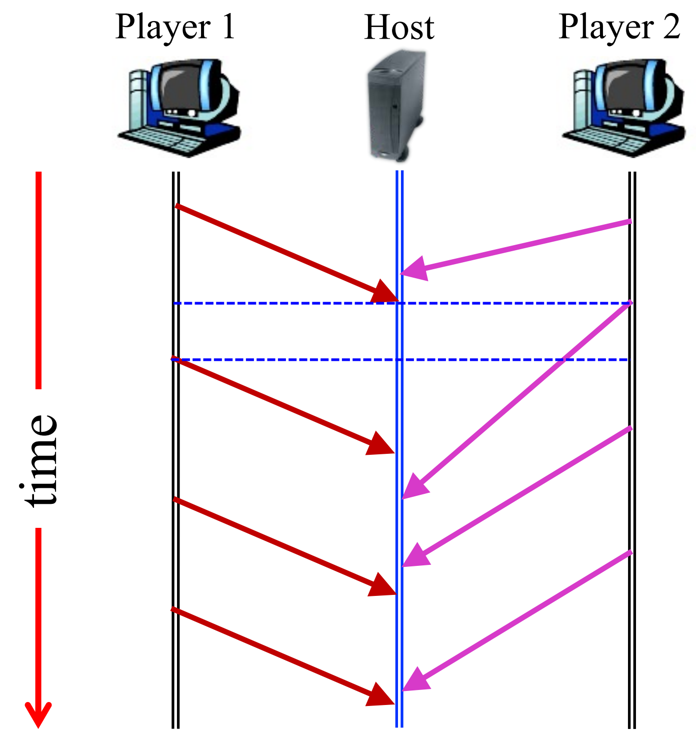
- Can interpolate late actions
  - Create simulation for action
  - Avg into original simulation
- Continue until converge



The Perils of Error Correction

CUGL Networking Guarantees

- CUGL built on **Slikenet**
  - Uses **reliable UDP**, not TCP
  - Uses **messages**, not stream
  - Messages are a **byte vector**
- Guarantees **message order**
  - Guarantees are **per client**
  - No guarantee between clients
- Host can **synchronize**
  - Host broadcasts moves to all
  - All clients see in **same order**



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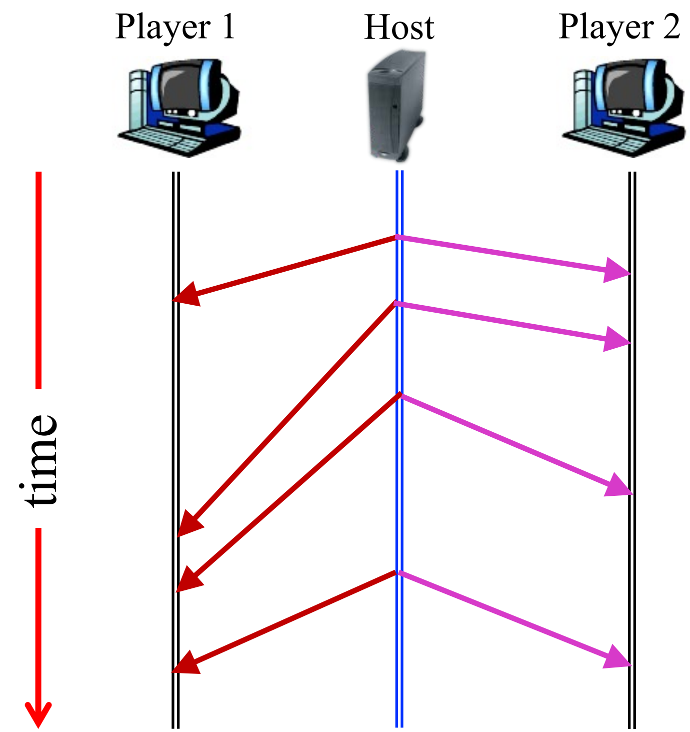

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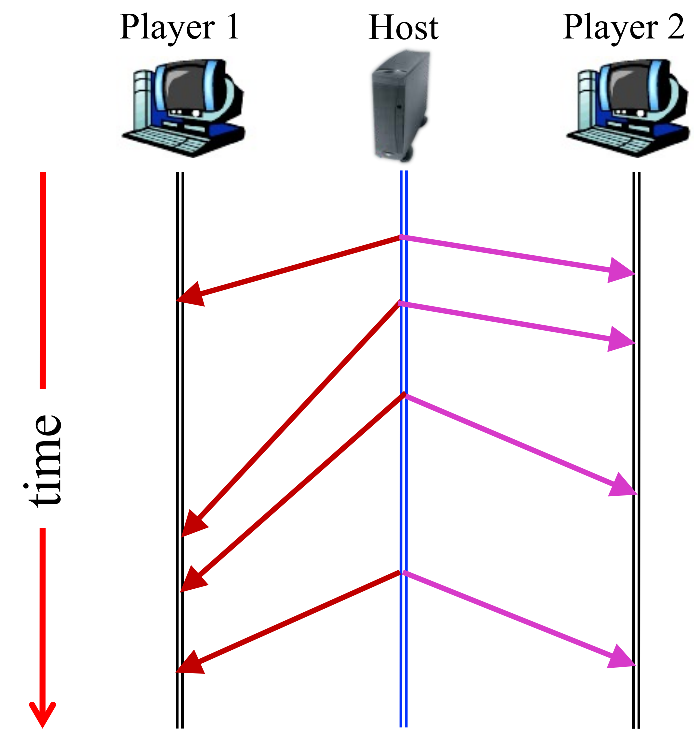
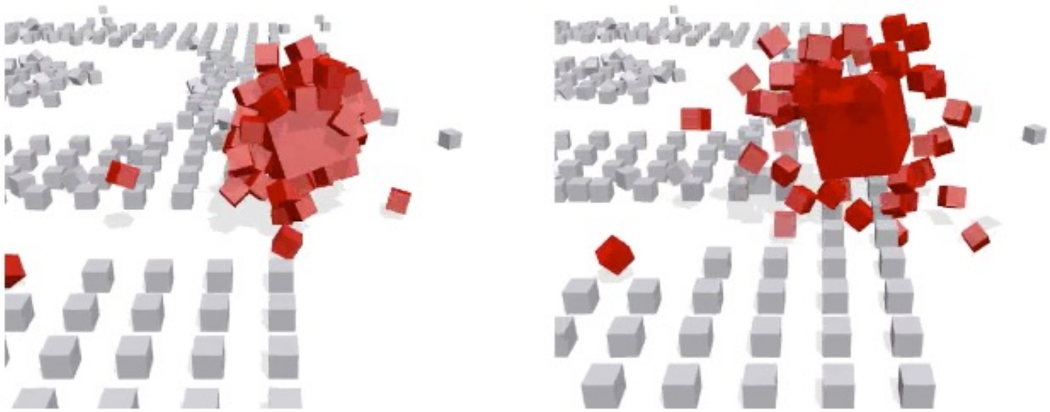
But introduces message *delay*



Physics: Challenge of Synchronization



- Deterministic bi-simulation is very hard
  - Physics engines have randomness (not Box2D)
  - Not all architectures treat floats the same
- Need to mix interpolation with snapshots
  - Like error correction in optimistic concern
  - Run simulation forward from snapshots

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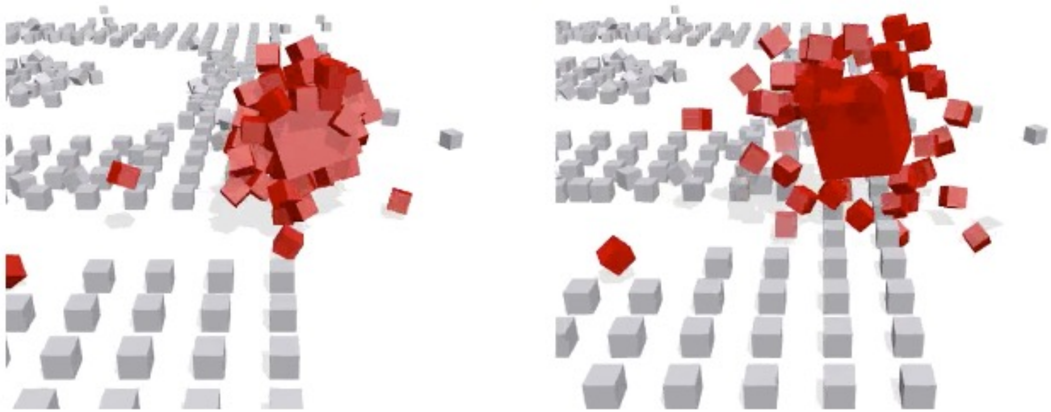

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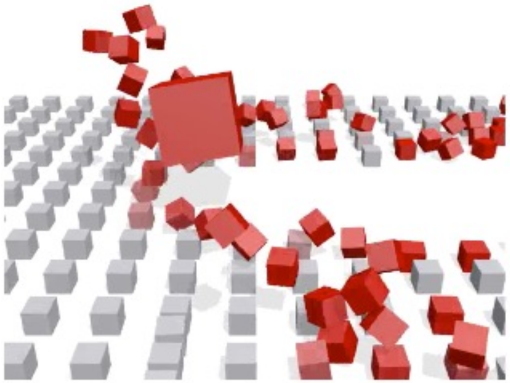
See today's reading

Physics: Challenge of Authority



- Distributed authority is very difficult
  - Authority naturally maps to player actions
  - Physics is a set of interactions
- Who owns an uncontrolled physics object?
  - **Gaffer:** The client that set in motion
  - Collisions act as a form of "authority tag"

Summary

- **Consistency:** local state agrees with world state
  - Caused by latency; takes time for action to be sent
  - Requires complex solutions since must draw now!
- **Authority** is how we measure world state
  - Almost all games use a centralized authority
  - Distributed authority is beyond scope of this class
- **Synchronization** is how we ensure consistency
  - Pessimistic synchronization adds a sizeable input delay
  - Optimistic synchronization requires a lot of overhead